

A 2.09-h Photometric Periodicity in GW Librae^{*}

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Abstract. We have found a 2.09 h modulation in brightness of the dwarf nova GW Lib. This bears no special relationship to the 1.28 h spectroscopic period that is believed to be the orbital period. It was present in May 2001, but not in observations made in 1997 and 1998 and is of unknown origin. Similar unexplained periodicities are present in FS Aur and V2051 Oph.

Keywords: dwarf novae, binary stars, cataclysmic variables

1. Introduction

GW Lib was discovered in 1983 as a ninth magnitude star (González 1983). It later faded to $m_v \sim 18.5$, on the basis of which (and in the absence of any spectroscopic observations) it was classified as a nova. Spectra obtained at minimum, however, show the emission lines and broad hydrogen absorption lines characteristic of a dwarf nova with very low rate of mass transfer (Duerbeck & Seitter 1987; Ringwald, Naylor & Mukai 1996; Szkody, Desai & Hoard 2000). As a result, it is clear that GW Lib is a member of the SU UMa class of dwarf novae, with very long interval between outbursts (see Warner 1995a,b for reviews of this class of cataclysmic variable star). No outburst other than that of 1983 has been observed; the amplitude of that suggests a superoutburst. GW Lib is therefore probably a system like WZ Sge.

Interest in GW Lib has been intensified by the discovery that its white dwarf primary has non-radial oscillations in the manner of a ZZ Cet variable (Warner & van Zyl 1998; van Zyl et al. 2000). The oscillations appear as brightness variations with maximum range ~ 0.03 mag and power in the regions of 236, 376 and 650 s. The spectral continuum and absorption line profiles give an effective temperature of $\sim 11\,000$ K (Szkody, Desai & Hoard 2000), which is consistent with the white dwarf component being in the ZZ Cet instability strip.

Extensive high speed photometric observations were obtained in March, April and September 1997 and in May 1998 (van Zyl et al. 2000). In none of these was any persistent brightness modulation detected that

^{*} This paper uses observations made from the South African Astronomical Observatory (SAAO).



Table I. Observing log.

Run No.	Date of obs. (start of night)	HJD of first obs. (+2452000.0)	Length (h)	t_{in} (s)	Tel.	$\langle V \rangle$ (mag)
S6217	18 May 2001	48.40493	4.88	20	40-in	16.9
S6219	20 May 2001	50.54336	2.49	20	40-in	16.8
S6221	21 May 2001	51.27101	4.98	20	40-in	17.0
S6227	23 May 2001	53.40757	3.51	15	74-in	16.9
S6230	26 May 2001	56.41459	5.29	20	74-in	17.0

could be ascribed to an orbital period. In particular, neither the spectroscopic period of 79.4 min obtained by Szkody, Desai & Hoard, nor the improved spectroscopic period of 76.78 min found by Thorstensen et al (2001), was present in the photometry.

In order to check that GW Lib is still behaving as in former years, we sampled the light curve in May 2001. The ZZ Cet oscillations were still prominently present, but in addition there was a clear periodic modulation with period near 2 h which encouraged us to investigate further.

2. Observations and Analysis

Our observing runs are listed in Table 1. Observations taken during the first week of observing were made with the 40-inch reflector at the Sutherland site of the South African Astronomical Observatory; the following week we moved to the 74-inch reflector. In both cases the University of Cape Town CCD photometer (O'Donoghue 1995) was attached to the telescope. In order to maximize the signal, observations were made in 'white light'.

The individual light curves are displayed in Figure 1 and an average light curve, with the mean brightness subtracted, is shown in Figure 2. In both Figures the abscissa is the phase in the 2.091 h period deduced below. Most of the rapid variation is due to the ZZ Cet pulsations. The continuous presence of a double peaked modulation with a period near 2 h and a peak-to-peak range of 0.10 mag is quite evident.

The Fourier amplitude spectrum of the entire data set (with the means, and linear trends subtracted for each night) is shown in Figure 3. The dominant peaks are at 7526 s and 7780 s (with uncertainties, due to noise, of a few seconds), but there is also significant amplitude

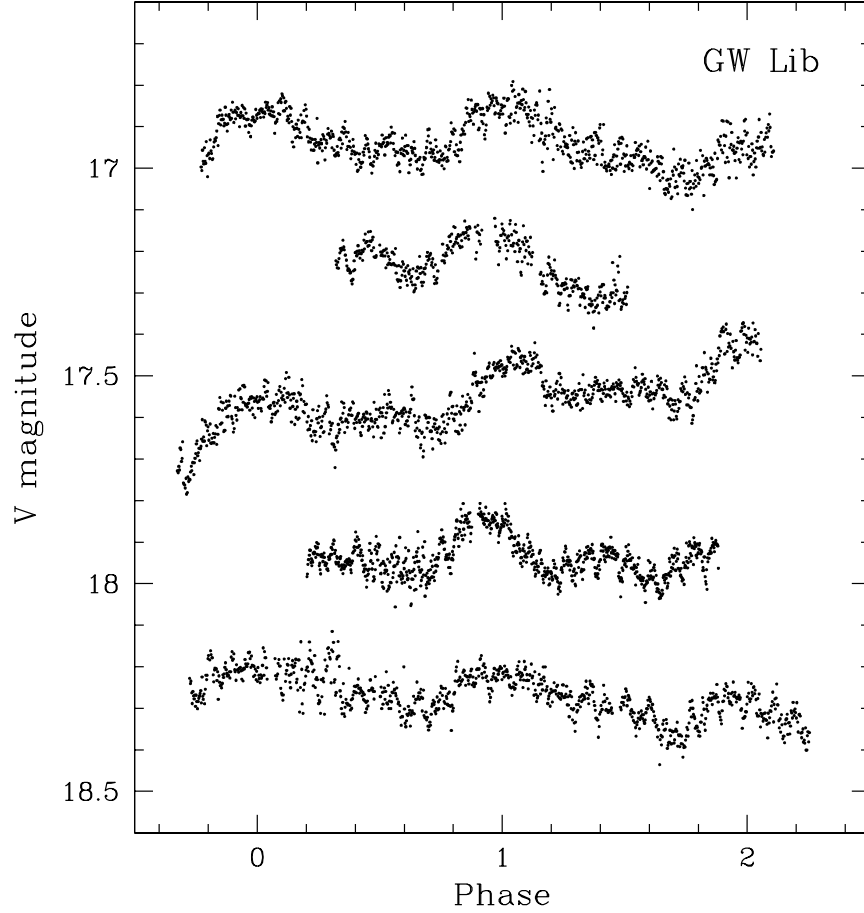


Figure 1. Light curves of GW Librae, phased according to the ephemeris of Eqn. 1. The upper curve is at the correct brightness. The others (in chronological order from top to bottom) have been displaced vertically by arbitrary amounts for display purposes.

in the vicinity of their first harmonic (and some evidence for a weak second harmonic). Prewhitening at either of the dominant periods removes most of the power in the region - the variable amplitude of the modulation probably causes the remaining power. The highest peaks at the first harmonic are at 3759 s and 3822 s. For both these, and the double peak at the fundamental, the separation of the peaks is caused by a $1/2.6 \text{ d}^{-1}$ alias that is present in the window pattern of the Fourier transform. The fact that the mean profile of the modulation (Fig. 2) contains an obvious first harmonic enables us to choose the 7526, 3759 s pair (marked by diagonal bars in Fig. 3) as the correct fundamental

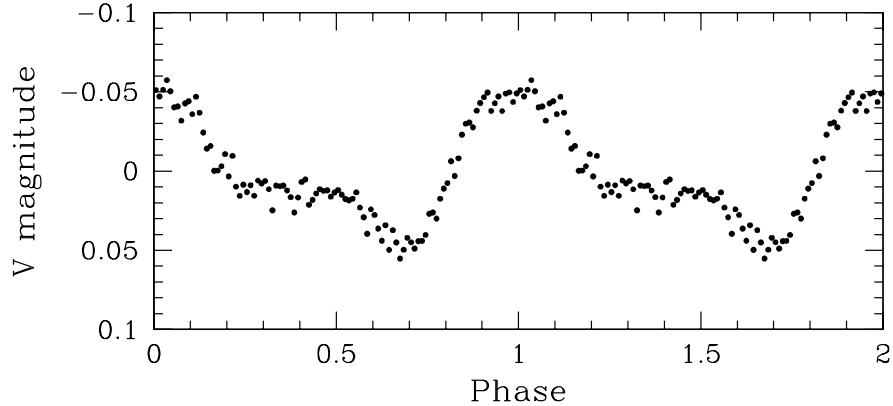


Figure 2. Mean light curve of GW Librae.

and its harmonic – the other pairings of frequencies do not have the necessary factor of two relationship.

From the fundamental period in the Fourier transform, we find the time of maximum light is given by the following ephemeris:

$$\text{HJD}_{\text{max}} = 2452048.42488 + 0^{\text{d}}.08711 \text{ E} \quad (1)$$

The modulation that we have found in GW Lib has therefore a doubled humped profile with a period of $7526 \text{ s} = 125.4 \text{ min} = 2.091 \text{ h}$, which persisted over a time of nearly two weeks. This neither equals nor bears any obvious simple relationship to the 76.78 min spectroscopic period found by Thorstensen et al. (2001). Prewhitening of our observations at the fundamental and first harmonic of the modulation does not reveal any significant signal near to the 76.78 min period.

The mean brightness of GW Lib during our 2001 observations was not detectably different (less than $\sim 0.1 \text{ mag}$ difference) from its brightness in 1997 and 1998. However, our light curves (Fig. 1) show evidence on some nights of slow systematic variations of $0.1 - 0.2 \text{ mag}$ about the mean.

3. Discussion

The essential issues that GW Lib raises are (a) the appearance of a strong periodic brightness modulation where there was none before and (b) the period itself, which is different from the spectroscopic value.

There are examples of orbital modulations, caused by the bright spot being obscured by the disc, which have disappeared for extensive lengths of time (e.g., HT Cas: Patterson 1981; Horne, Wood & Stiening

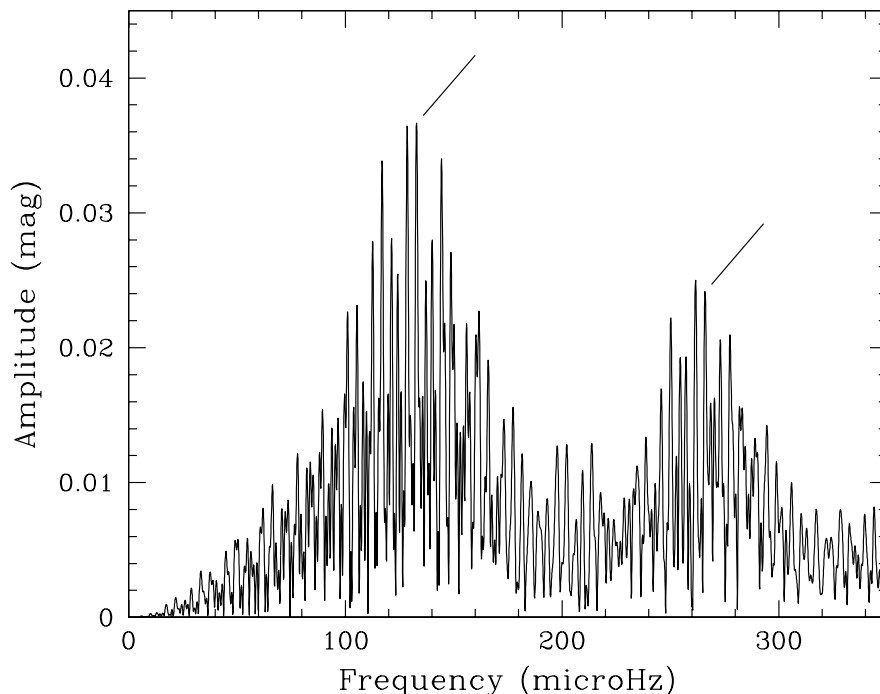


Figure 3. Fourier spectrum of GW Librae. The fundamental and first harmonic of the 2.091 h period are marked by diagonal bars.

1991) and which may be the result of the disc becoming optically thin. The long outburst interval in GW Lib is characteristic of SU UMa stars with a period around 80 min (Warner 1995b), which have very low mass ratios and consequently are prone to develop elliptical accretion discs and their associated superhumps. The latter arise from stresses in the disc caused by the orbital passage of the secondary star, and are thus visible even in very low inclination systems. It could be, therefore, that the periodic modulation that we see in GW Lib is the result of the development of superhumps – the double hump profiles are consistent with this. If this is the case, then the orbital period of GW Lib would be a few percent shorter than the 2.09 h that we measure.

On the other hand, there is no doubt that there is a clear periodic signal in the spectroscopy, with Szkody, Desai & Hoard (2000) and Thorstensen et al. (2001) both detecting signals (but the latter using more extensive and better distributed observations). Both spectroscopic and photometric periods can, in various systems, be identified as the orbital period or the spin period of one of the components. There is no evidence in GW Lib (from the spectrum) of any strong magnetic field, so the two periods are unlikely to be orbital and white dwarf

rotation, as they often are in intermediate polars (e.g. 98 min and 67 min respectively in EX Hya). The ratio of photometric to spectroscopic periods is only 1.64, and even if the beat between the two periods is thought to be relevant, the ratio of beat and spectroscopic periods is only 3.27. These low values appear to rule out any disc precession as the possible generator of the photometric period.

There is evidence that a similar dilemma occurs in another system. FS Aur has a spectroscopic period of 85.7 min (Thorstensen et al. 1996), which has also been seen by Neustroev (2001), but the latter finds in addition photometric variations with range of about 0.25 mag and a possible period around 3 h. This period needs to be confirmed by more extensive photometry; there is no sign of the spectroscopic period in the existing photometry.

Another anomalous system is V2051 Oph, in which the orbital period is definitively established from eclipses as 89.9 min. Warner & O'Donoghue (1987), from photometry at quiescence, found a brightness modulation with range ~ 0.15 mag and period $\sim 16\,500$ s (274 min) which was present for several nights during two observing runs a month apart. The ratio of periods in this case is 3.05.

We do not have a physical explanation for the longer periods in GW Lib, FS Aur and V2501 Oph. Long term photometric studies, to examine the stability of the periods, and simultaneous photometry and spectroscopy may assist in developing a model.

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